

Compositions based on aqueous asphalt and polyurethane
dispersions, method of preparation and uses

The present invention relates to the field of
5 emulsified asphalts, in particular to the field of
asphalts in the form of an emulsion (or aqueous
dispersion) that are modified by an aqueous polymer
dispersion and more particularly to the field of
10 emulsified asphalts modified by an aqueous dispersion
of a specific polyurethane.

The use of asphalt-polymer blends is well known,
particularly in the road field and in the waterproofing
field, in particular in the form of membranes and
15 coatings. The incorporation of polymers into asphalts
modifies their properties so as to improve the thermal
behaviour, which is characterized by an increase in the
flow (creep) temperature and by a reduction in the
stiffening (cracking) temperature, with as a
20 consequence an improvement in the elongation, the
tensile strength and the tear strength.

Among the various industrial applications of asphalt
emulsions, mention may be made, for example, of the
25 production of surface coats, waterproof courses under
asphalt road mixes, asphalt road mixes, slurry seals or
cold cast mixes, agglomeration binders, protective
coverings for pipes, carpet underlay impregnation and
tie layers, soundproofing and damping coverings. In all
30 cases, these involve a dispersion of asphalt or
bituminous substance in an aqueous phase obtained using
a surfactant and by supplying energy provided either by
a colloidal mill or by any other device suitable for
forming the dispersion. In general, and depending on
35 the type of emulsifier used in preparing the emulsion,
two types of emulsions may be distinguished, namely
anionic aqueous emulsions and cationic aqueous
emulsions.

The first (i.e. anionic) emulsions generally find their applications in the building and public works (BPW) sector or the construction and civil engineering sector for waterproof membranes, bonding coats and external protective coatings. In particular, they are very widely used in the field of roofing membranes (for flat roofs and built-up roofs). The essential properties for these applications are the elasticity of the asphalt, good high-temperature resistance (low creep) and good low-temperature resistance (cracking resistance), and also good adhesion to steel and concrete substrates and low water absorption (i.e. good impermeability). This is because the asphalts used in roofing membranes must withstand large seasonal variations in temperature with lifetimes of several years. Emulsified asphalts not modified by a polymer additive do not in general result in satisfactory performance. This is because the mechanical properties of asphalts are very temperature-sensitive. They often become too rigid and brittle at winter temperatures, whereas they have a tendency to creep at high temperatures, for example in the summer. Moreover, asphalts generally have a low adhesion to conventional substrates, such as concrete and steel. It is therefore often necessary to apply a primer layer, which entails additional production costs. Finally, their impermeability and their chemical resistance are often insufficient.

The second (i.e. cationic) emulsions are used in general as a binder in the construction or repair of road pavements. The properties that it is desired to improve are therefore the rutting resistance (i.e. the ability of the asphalt to withstand abrasion, creep and ageing induced by vehicular traffic), low-temperature cracking resistance and adhesion to the aggregates.

US 4 724 245 discloses a method that consists in preparing a blend of asphalt and hydroxytelechelic

polybutadiene denoted hereafter by HTBD, and in emulsifying it in aqueous phase, the crosslinking taking place by addition of polyisocyanate dispersed in aqueous phase.

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Patent US 3 909 474 discloses a similar method based on a preoxidized asphalt, the crosslinking taking place by oxidation of the HTBD.

10 Patent US A 3 932 331 discloses a method for rapidly breaking and hardening an asphalt emulsion by incorporating therein an isocyanate (NCO)-terminated urethane prepolymer. When the prepolymer is added to the asphalt emulsion, this makes it impossible to store
15 the asphalt-polymer emulsion blend since the isocyanate reacts with the water of the emulsion.

DE 40939151 discloses a composition obtained by the reaction of a prepolymer with a dispersion of an
20 unsaturated olefin compound, of polyurethane or of asphalt.

DE 4408154 discloses a coating based on an asphalt emulsion containing a polyurethane prepolymer with NCO
25 terminal groups.

Most of these methods, known in the prior art, require the use of reactive two-component (2K) compositions with the necessary presence of an isocyanate component
30 and strict control of the operating conditions both from the environmental/health/safety standpoint and the technical standpoint in terms of strict dosing of the reactive components in order to achieve satisfactory performance. More particularly, owing to the
35 application conditions often imposed (e.g. environmental constraints: temperature and humidity), the structure and the applicative performance of the end product are often very difficult to reproduce. Moreover, the changing reaction of the isocyanate

component may very well disturb the fragile stability of the dispersion in its entirety.

5 The present invention remedies these problems by proposing a solution based on an aqueous polymer composition equivalent to a nonreactive one-component (1 K) composition. Indeed, there is complete absence of a reactive component liable to be affected by the operating conditions during application or to affect
10 its processing conditions in terms of health, safety or the environment by its use.

The first subject of the present invention is therefore an aqueous polymer composition comprising:

- 15 a) at least one aqueous asphalt dispersion; and
b) at least one aqueous dispersion of at least one polyurethane, this polyurethane being obtained from a polyol component containing at least one hydroxylated polydiene.

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Another subject of the invention is a method of preparation of the composition defined according to the invention, by simple physical blending of an aqueous asphalt dispersion with an aqueous polyurethane
25 dispersion, the two emulsions being compatible. This method makes it possible to modify the asphalt and to improve all of its properties, and consequently to offer novel technical solutions in the BPW membrane sector and the construction and civil engineering
30 sector. This method has the advantage of proposing a one-component system containing no free isocyanate (free NCO), which is homogeneous and stable. In addition, the asphalt-polymer film forms and hardens by simple water evaporation under the ambient application
35 conditions.

Another subject of the invention is a coating composition comprising at least one aqueous polymer composition as defined according to the invention.

Another subject of the invention is the use of an aqueous polymer composition of the invention in the production of surface coats, waterproof courses under asphalt road mixes, roofing membranes, asphalt road mixes, slurry seals or cold cast mixes, agglomeration binders, protective coverings for pipes, carpet underlay impregnation and tie layers, soundproofing and damping or insulating coverings.

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The invention also relates to a method of use of the aqueous polymer composition as defined according to the invention, which comprises the following steps:

- 15 a) blending of at least one aqueous asphalt dispersion with at least one aqueous dispersion of at least one polyurethane as defined according to the invention;
- b) direct application of the blend obtained in step a) to the application object or substrate;
- 20 c) drying/film-forming by simple water evaporation; it being possible for the three steps a), b) and c) to be carried out on the actual site of the application and under the ambient conditions of the application site.

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A final subject of the invention relates to end products such as coatings, surface coats, waterproof courses under asphalt road mixes, roofing membranes, asphalt road mixes, slurry seals or cold cast mixes, agglomeration binders, protective coverings for pipes, carpet underlay impregnation and tie layers, soundproofing and damping or insulating coverings obtained according to the method of use of the invention or from an aqueous polymer dispersion composition as defined according to the invention.

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Specifically, the Applicant has discovered that the addition of an aqueous polyurethane dispersion, denoted hereafter by PUD, into an aqueous asphalt dispersion

(emulsion) makes it possible to obtain a storage-stable blend and to very significantly improve the mechanical performance in terms of thermal withstand at low and high temperatures (stiffening problem and creep resistance) and in particular the mechanical properties, such as the tensile strength and the elongation at the break of the modified asphalt that results from the presence of the PUD. In addition, the properties of adhesion of the asphalt to steel or concrete are considerably improved, as is the water vapor impermeability for applications such as membrane or sealing layers.

The Applicant has also discovered that when the polyurethane dispersion is produced from a hydroxytelechelic polybutadiene (HTBD), the chemical resistance properties are particularly improved.

According to the invention, the aqueous polyurethane dispersion may be prepared using a method described in WO 99/4894, which comprises the following steps:

- (a) formation of a prepolymer having NCO functional groups by reaction in a solvent:
 - of a polyisocyanate component, and
 - of a polyol component comprising a diol, carrying at least one neutralized acid functional group, the NCO functional groups being in excess relative to the OH functional groups, and in a ratio of between 1.5 and 2.5,
- (b) dispersion of the prepolymer in water,
- (c) addition of a diamine-type chain extender, and
- (d) evaporation of the solvent in order to obtain an aqueous polyurethane dispersion containing urea functional groups.

The polyurethane component of the aqueous polymer dispersion composition according to the invention

represents from 2 to 50% and preferably from 5 to 25% by weight relative to the total asphalt + polyurethane weight, the weight being expressed as dry matter.

5 Preferably, the hydroxylated polydiene is chosen from hydroxytelechelic conjugated-diene oligomers that can be obtained by various methods such as the radical polymerization of conjugated dienes having from 4 to 20 carbon atoms in the presence of a polymerization
10 initiator, such as hydrogen peroxide or an azo compound, such as 2,2'-azobis[2-methyl-N-(2-hydroxyethyl)propionamide], or the anionic polymerization of conjugated dienes having from 4 to 20 carbon atoms in the presence of a catalyst, such as
15 dilithium naphthalene.

According to the present invention, the polyol component of the polyurethane consists of at least 50% and preferably at least 80% by weight of at least one
20 hydroxytelechelic conjugated-diene oligomer. This is preferably selected from hydroxytelechelic oligomers derived from: butadiene, isoprene, chloroprene, 1,3-pentadiene, cyclopentadiene and mixtures thereof. The number-average molecular weight of the oligomers
25 that can be used may vary from 500 to 15 000 and preferably from 1000 to 3000, the hydroxyl number expressed in milliequivalents per gram (meq/g) is from 0.5 to 5 and preferably from 0.7 to 1.8, and their viscosity is between 1000 and 10 000 mPa.s.

30 Preferably, a butadiene-based and more particularly hydroxytelechelic polydiene-polyol will be used. Advantageously, the polydiene-polyol comprises 70 to 85 mol%, preferably 80 mol%, of 1-4 units and 15 to 30
35 mol%, preferably 20 mol% of 1-2 units. As an illustration of polydiene-polyols, mention may be made of hydroxyl-terminated polybutadiene sold by Atofina under the brand names PolyBd[®]R45 HT and PolyBd[®]R20 LM. Hydroxylated copolymers of conjugated dienes with vinyl

and/or acrylic monomers, such as styrene or acrylonitrile, may also be suitable as hydroxylated polydienes. Likewise, in-chain-epoxidized hydroxytelechelic butadiene oligomers or else
5 hydroxytelechelic conjugated-diene oligomers, when partially or completely hydrogenated, may be suitable for this use.

The diol carrying at least one neutralized acid
10 functional group may be triethylamine-neutralized dimethylolpropionic acid.

A short diol may also form part of the polyol component used for the preparation of the polyurethane. As
15 examples of such diols, mention may be made of 2-ethyl-1,3-hexanediol, N,N'-bis(2-hydroxypropyl) aniline. The amount of such a diol is advantageously between 1 and 30 parts by weight per 100 parts of hydroxyl-terminated polydiene.

20 According to the present invention, the polyisocyanate used for the preparation of the aqueous polyurethane dispersion may be an aromatic, aliphatic or cycloaliphatic polyisocyanate having at least two
25 isocyanate functional groups in its molecule.

A way of illustration of aromatic polyisocyanates, mention may be made of 4,4'-diphenylmethane diisocyanate (MDI), liquid modified MDIs, polymeric
30 MDIs, 2,4- and 2,6-tolylene diisocyanate (TDI) and mixtures thereof, xylylene diisocyanate (XDI), triphenylmethane triisocyanate, tetramethylxylylene diisocyanate (TMXDI), paraphenylene diisocyanate (PPDI) and naphthalene diisocyanate (NDI).

35 Among the aromatic polyisocyanates, the invention preferably relates to 4,4'-diphenylmethane diisocyanate and most particularly to liquid modified MDIs.

By way of illustration of aliphatic polyisocyanates, mention may be made of hexamethylene diisocyanate (HDI), and its derivatives, trimethylhexamethylene diisocyanate.

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By way of illustration of cycloaliphatic polyisocyanates, mention may be made of isophorone diisocyanate (IPDI), and its derivatives, 4,4'-dicyclohexylmethane diisocyanate and cyclohexyl diisocyanate (CHDI).

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A catalyst may be added, which may be chosen from the group comprising tertiary amines, imidazoles and organometallic compounds.

By way of illustration of a tertiary amine, mention may be made of diaza-1,4-bicyclo[2.2.2]octane (DABCO).

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By way of illustration of organometallic compounds, mention may be made of dibutyltin dilaurate and dibutyltin diacetate.

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The amounts of catalyst may be between 0.01 and 5 parts by weight per 100 parts by weight of polyol (hydroxyl-terminated polydiene and diol with an acid functional group).

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The amount of isocyanate is advantageously such that the NCO/OH molar ratio is greater than 1.4 and preferably between 1.5 and 2.5. The OH functional groups are those of hydroxylated polydiene and of the diol with an acid functional group and of the short diol.

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The amount of diol containing neutralized acid functional groups is advantageously such that there are 0.2 to 2.5 carboxylate functional groups per hydroxyl-terminated polydiene chain. The presence of a solvent is necessary in order to allow the prepolymer to be

synthesized, this solvent having to be easy to remove in step (d). It is preferred to use methyl ethyl ketone (MEK). This step (a) is carried out in conventional stirred reactors.

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The amount of water in step (b) is such that, in step (d), a dispersion containing from 20 to 60 and preferably from 30 to 50 wt% of solid matter (SC : Solids Content) is obtained. In step (b), the water is
10 advantageously introduced into a stirred reactor. This step (b) may or may not be carried out under pressure, but it is simpler to be at atmospheric pressure. The temperature of this step may vary from room temperature (20°C) to 80°C, and it is preferably at room
15 temperature (20°C).

As chain extender in step (c), mention may be made of a diamine-type extender and more particularly hydrazine in aqueous solution or ethylenediamine or
20 isophoronediamine or hydroxylamine. The extension reaction may be carried out at a temperature ranging from room temperature to 80°C, and preferably at room temperature and at atmospheric pressure. The extension of the chains in the dispersion may be monitored by
25 volumetric analysis of the isocyanate functional groups over the course of time. The reaction time is around 10 minutes.

Step (d) may be carried out, for example, by a
30 distillation using a standard device.

The aqueous dispersions obtained do not contain a substantial amount of solvent (preferably less than 5%), they have a low viscosity, for example from 4 to
35 10 mPa.s and they have a solids content (SC) of 20 to 60% and preferably of 30 to 50% by weight.

As regards the method of preparation of the aqueous polymer composition according to the invention, the

proportions of the respective asphalt and polyurethane dispersions are in a weight ratio ranging from 2 to 75% of dispersion, for asphalt and polyurethane dispersions having solids contents that can be independently varied
5 within a range from 20 to 60% by weight, and preferably from 30 to 50% by weight, of each dispersion.

As regards the coating compositions according to the invention, these may serve for the production of
10 coatings or coats for protection, sealing or waterproofing, soundproofing, or damping, for road and roof applications, in buildings or in industry.

The following examples illustrate the invention without
15 limiting the scope thereof.

EXAMPLES

An aqueous polyurethane dispersion was typically
20 obtained from an isocyanate-terminated urethane prepolymer containing anionic (i.e. carboxylic) or cationic functional groups so as to allow emulsification. This prepolymer was firstly neutralized and dispersed in water. The next step consisted in
25 increasing the molecular weight or carrying out a chain extension by the addition of a diamine in order to obtain a polyurea polyurethane (PUD) dispersion. It would have been possible, for example, without this being restrictive as regards the type of PUD covered by
30 the present patent, to choose an anionic PUD obtained from a hydroxylated polybutadiene as described in patent application No. FR 98/03793.

Aqueous polyurethane dispersion	
Composition	Anionic polyurethane dispersion based on hydroxylated polybutadiene (PolyBd R45HT [®] from Atofina)
Solids content	37.9% by weight
pH	7.3

This aqueous polyurethane dispersion was added to an asphalt in aqueous emulsion with an uncharged cellular structure (the emulsion being able to be used as a multipurpose asphalt-based coating for sealing, bonding, insulating, protecting and tiling). These two emulsions were blended at room temperature using a blade stirrer rotating at low speed for 10 minutes in the following proportions by weight [m1, m2]: [0,100], [5,95], [10,90], [20,80], [50,50], [75,25] and [100,0], where m1 represents the mass of aqueous PUD polyurethane dispersion and m2 the mass of asphalt emulsion.

Asphalt emulsion	
Composition	Anionic asphalt emulsion
Solids content	48% by weight
pH	9.5

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Storage stability

The storage stability of the emulsion blends was monitored over a period of 1 month at room temperature. It was possible to obtain stable blends with PUD contents ranging up to 50 parts by weight per 50 parts by weight of asphalt dispersion, no phase separation being observed. The storage stability is therefore deemed to be good. The results are given in detail in Table 1 below.

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Table 1: Evaluation of the stability of the blend as a function of the PUD/asphalt dispersion composition after being stored for one month.

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Evaluation of the hot and cold properties

All the specimens were analyzed by DMA so as to monitor the change in the properties with temperature and more
5 precisely to determine the influence of the PUD modifier content on the upper and lower operating limits of the asphalt. The moduli E' (dynamic storage modulus) and E'' (dynamic loss modulus), and also the loss factor $\tan\delta$ ($= E''/E'$), were measured by DMA
10 analysis between -100°C and $+100^{\circ}\text{C}$ at a frequency ω of 10 rad.s^{-1} .

A high temperature limit was able to be demonstrated. This temperature corresponds to the flow point of the
15 asphalt, and beyond this point the properties of the specimen could no longer be measured and the test was therefore stopped. In the case of the [100/0] asphalt, the flow point, as defined above, was at $T[100/0] = 31^{\circ}\text{C}$. This temperature clearly increases when the
20 bitumen is modified by the PUD ("asphalt emulsion" / "PUD" parts by weight in brackets). Thus, a $T[95/5]$ of 54.7°C was obtained and then a $T[90/10]$ of 66.7°C and a $T[80/20] > 100^{\circ}\text{C}$ were obtained, as indicated in Table 2.

25 As in the case of the determination of a low temperature limit, we set a stiffening criterion T^* as being the temperature at which the modulus E' (dynamic storage modulus determined by DMA at the frequency ω of 10 rad.s^{-1}) of the modified asphalt increases by half a
30 decade relative to the modulus E' at room temperature ($\text{RT} = 20^{\circ}\text{C}$). According to this criterion, we therefore obtained a T^* [100/0] of $+4^{\circ}\text{C}$ in the case of the control asphalt and then a T^* [95/5] of -18.1°C , a T^* [90/10] of -9.9°C , a T^* [80/20] of -11.9°C , a T^*
35 [50/50] of -32.6°C and finally a T^* [25/75] of -53.3°C in the case of the modified asphalts.

Table 2:

Measurement of the flow and stiffening temperatures as a function of the PUD/ asphalt dispersion composition (PU: dry polyurethane)

Anionic HTBD-based polyurethane dispersion (parts by weight)	0	5	10	20	50	75	100
	100	95	90	80	50	25	0
Amount in % of dry polyurethane (PU) in the blend (solids ratio by weight)	0	3.98	8.06	16.48	44.12	71.64	100
T (flow point) °C	31	54.7	66.7	> 100	> 100	> 100	> 100
T* (stiffening point) °C	4	-18.1	-9.9	-11.9	-32.6	-53.3	-62.2

These measurements clearly show that the plasticity range of the control asphalt is widened by the use of PUD as modifier. The high-temperature properties (i.e. creep) are improved as is the low-temperature cracking resistance.

Evaluation of the adhesion to steel

The various PUD-modified asphalt emulsions were then applied as a 1 mm thick film to steel. The steel substrate selected was a conventional steel (low-carbon mild steel) surface-treated beforehand by shot peening. An adhesion-to-steel test was carried out according to the Renault D51 1755 standard, which consists in adhesively bonding a circular stud with a diameter \varnothing of 20 mm to the coating by means of a two-component epoxy adhesive (ARALDITE from Ciba-Geigy). This stud was then pulled at a rate of 10 mm/min on a tensile testing machine in the arrangement described below. The maximum tear force and the failure mode (cohesive or adhesive failure) were then noted.

The asphalt alone showed only very weak adhesion to shot-peened steel. When the amount of modifier was increased, the adhesion improved very substantially. An adhesion of 1.38 MPa obtained for the [5/95] PUD/asphalt emulsion blend was 1.38 MPa, then 3.37 MPa for the [20/80] blend and greater than 4 MPa for the [50/50] and [75/25] blends. The results are given in Table 3.

Evaluation of the adhesion to concrete

For these tests, we used concrete slabs of dimension 40 × 40 × 5 cm of the LUCIANA reference type. They were dedusted and rinsed in water beforehand, and then placed for at least 24 hours in fan oven at 50°C in order to dry them. The various PUD-modified emulsions were then poured onto the concrete slab to form a

coating about 1 mm in thickness. The coated slab was left for one week at ambient temperature and humidity. An adhesion test as described above was then carried out. The results confirmed that the adhesion properties of the asphalt are improved by the addition of PUD, particularly with contents of between 10 and 20%, for which cohesive failure in the concrete substrate was observed. The results are given in the summarizing Table 3.

Evaluation of the water vapor permeability

Films 2 mm in thickness were produced from the various PUD-modified asphalt emulsions. The specimens were placed for 2 hours in a fan oven at 50°C and then for one week at room temperature in the laboratory in order to complete the film-forming process, before being cut into test pieces. The water vapor permeability measurements were carried out according to the ASTM E 96 E standard (38°C/90% relative humidity RH). A considerable improvement in the impermeability properties of the film was observed thanks to the use of PUD. The results are given in the summarizing Table 3.

Evaluation of the mechanical properties

Films 2 mm in thickness were produced from the various PUD-modified asphalt emulsions. The specimens were placed for 2 hours in a fan oven at 50°C and then for one week at room temperature in the laboratory in order to complete the film-forming process, before being cut into test pieces for the mechanical tests. The tensile strength was almost zero in the case of bitumen alone, whereas values well above 1 MPa were obtained with a dry PU (polyurethane) modifier polymer content of around 16%. This tensile strength, like the elongation at break, increases with increased PU modifier polymer content (see Table 3).

Table 3:

Summary of the properties of the modified asphalts as a function of the PUD/asphalt dispersion composition

Anionic HTBD-based polyurethane dispersion (parts by weight)	0	5	10	20	50	75	100
Anionic asphalt emulsion (parts by weight)	100	95	90	80	50	25	0
Dry PU content in the blend (amount by weight per 100 parts of solids)	0	3.98	8.06	16.48	44.12	71.64	100
Adhesion to steel (Renault D51 1755)	MPa	0	1.38	-	3.37	cohesive asphalt	cohesive asphalt
Adhesion to concrete (Renault D51 1755)	kN	2.66	cohesive asphalt	cohesive concrete	cohesive concrete	cohesive concrete	cohesive adhesive
Water vapor permeability (ASTM E96E)	g.500 µm/mm ² 24h	295.2	247.5	102.4	103.38	16.68	15.7
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Tensile strength (ASTM D412-98a)	MPa	≈ 0	≈ 0	≈ 0	1.4	2.1	2.6	5.1
Elongation at break (ASTM D624- 00e1)	%	≈ 0	≈ 0	≈ 0	19	80	265	413
Tear strength (ASTM 2240-00)	N/mm	Not measurable	Not measurable	Not measurable	13.7	17.1	17.8	21.6
Hardness	Shore A	Not measurable	Not measurable	Not measurable	63	70	69	70
T (flow point)	°C	31	54.7	66.7	> 100°	> 100°	> 100°	> 100 °
T* (stiffening point)	°C	4	-18.1	-9.9	-11.9	-32.6	-53.3	-62.2